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Effectiveness of Träbert current in a physiotherapy program for the management of musculoskeletal pain: a systematic review and meta-analysis

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Abstract

Introduction. Träbert current (TC) is a physical therapy resource described for the management of musculoskeletal pain (MSP). It combines the effects of galvanism and sensory stimulation, offering various analgesic applications, although it seems that the studies that support its effectiveness are limited. The aim of this study was to evaluate the effectiveness of TC in a physical therapy plan for the management of MSP.

Methods. Electronic databases reviewed included Medline (via PubMed), Web of Science, Scopus, CINAHL, Science Direct, and PEDro (last updated January 12, 2024). Randomised clinical trials (RCTs) comparing TC with other physical therapy interventions were included. Seven studies met the inclusion criteria and were analysed qualitatively, while five contributed to the meta-analysis. The clinical conditions treated included knee osteoarthritis, low back pain (LBP), and epicondylalgia. The risk of bias and internal validity was evaluated using the Rob2 tool (Cochrane) and the PEDro scale.

Results. RCTs were rated as having favourable internal validity (PEDro), despite a lack of concealed allocation and blinding, resulting in an unclear risk of bias on D2 and D5 (Rob2). The studies reported a decrease in pain and disability for the experimental groups ($p < 0.05$), although the meta-analysis revealed a non-significant pooled effect for the standardised mean difference (SMD = 0.2–0.5, $p > 0.05$) in favour of the controls and with heterogeneity between the studies ($I^2 = 50–75\%$).

Conclusions. TC seems to be effective for the management of MSP, although it is necessary to improve the quality of the clinical trials to conduct a conclusive quantitative analysis.

Key words: systematic review, transcutaneous electrical nerve stimulation, electrical stimulation therapy, Träbert current, musculoskeletal pain, musculoskeletal diseases

Introduction

Musculoskeletal pain (MSP) is currently a health concern, representing one of the more important sources of chronic pain and causes of disability in adults [1]. The prevalence of MSP in the population has been estimated between 14 and 47%, showing evolution to chronic musculoskeletal disorders in 11 and 24% of cases, respectively, resulting in increased care and higher economic costs for health systems [2, 3]. Unfortunately, because of the direct link between musculoskeletal disorders and age, a sedentary lifestyle, and increased life expectancy [1, 3], these are on the rise. MSP comprises various local and neuropathic pain disorders, with shoulder, lumbar, and cervical spine pain conditions being the most frequent, followed by degenerative joint problems and rheumatoid diseases that usually appear at older ages [4, 5].

Moreover, the International Association for the Study of Pain (IASP) has recognised the challenges involved in the treatment of MSP, especially when it comes to chronic pain conditions in which diagnosis is difficult. In most cases, pain is controlled but not resolved, affecting people's quality of life as well as the costs associated with socioeconomic status [6, 7].

MSP has been commonly managed through pharmacological treatment with non-steroidal anti-inflammatory drugs (NSAIDs), steroidal anti-inflammatory drugs (SAIDs), and opioids [8, 9]. However, the persistence or recurrence of symptoms is not uncommon in these treatments, especially in chronic conditions, adding to the dependence and side effects that patients exhibit on medications. Furthermore, the use of these drugs has been linked to placebo effects rather than to the effects of the medication itself [1, 9, 10]. Current clinical recommendations have suggested non-pharmacological management as the first line of treatment for MSP, especially when dealing with chronic pain [1, 3]. In this sense, the role of physical therapy is fundamental, offering another alternative for people with disorders of the musculoskeletal system who are seeking to reduce pain and improve functionality [11]. Physical therapy interventions include manual therapy, therapeutic exercise, physical agents, and various electrotherapy modalities, all of which are supported by current practice guidelines [1, 12].

Electrotherapy includes a wide variety of analgesic currents, with the most traditional resources being sensitive transcutaneous electrical stimulation (TENS) and medium-frequency burst-modulated alternating currents (BMAC) [13–15]. However, a lot of equipment offers lesser-known modalities, especially in the low-frequency range (1–1000 Hz), with biophysical properties that differ from traditional modalities [16, 17]. The Träbert current (TC), also known as the 2–5 current Hz or Ultra-Reiz current, is a low-frequency current with analgesic effects described at the beginning of the 20th century before the appearance of TENS [17–19]. It is characterised by rectangular pulses of 2 milliseconds (ms) and 5 ms intervals with a fixed frequency of 143 Hz, characteris-

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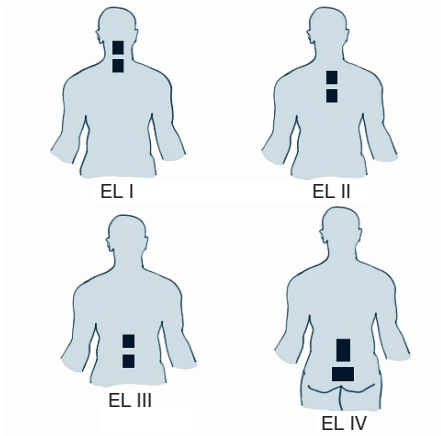

Figure 1. Träbert electrode placement (longitudinal application): EL I, anode at C2 and cathode at C6; EL II, anode at C7 and cathode at T6; EL III, anode at T12 and cathode at L2; EL IV, anode at L2 and cathode at S1 (horizontal)

tics that allow it to combine the galvanic and sensitive properties of TENS [17]. Their intensities are usually high (tolerance level or maximum supported non-nociceptive stimulation) with times between treatments of 10 to 15 minutes [17].

The galvanic properties are related to the electrolysis and electrophoresis of biological molecules, triggering electrochemical changes under the electrodes (polar effects), estimating a galvanic component of 28.5% for TC [17, 20]. On the other hand, the sensory properties have been associated with the stimulation of large afferent fibres (A-beta), which would result in analgesic modulation mediated by the gate theory (Melzack-Wall theory) and/or endogenous opioid peptide release [21, 22]. In addition, spinal applications (longitudinal applications or Träbert positions) have been described (Figure 1) using stimulation intensities at the tolerance level (A-delta and C fibre activation), which would result in pain modulation mediated by diffuse noxious inhibitory control (DNIC), a descending system activated when there are two simultaneous painful stimuli [23, 24]. Bipolar applications are also described, placing both opposite electrodes on joints (transregional application), or applications on painful points using the cathode (application on sensitive point) [17].

Although most electrotherapy equipment currently offers clinicians the choice of TC, its use is not very widespread, probably due to a lack of knowledge of its potential therapeutic effects. The combination of galvanic and sensitive effects makes TC a versatile therapeutic resource concerning pain management. Thus, the objective of this systematic review (SR) is to investigate the available scientific evidence regarding the effectiveness of TC in the management of MSP in physical therapy treatments.

Subjects and methods

Study design

This SR with meta-analysis (MT-A) following the guidelines of the PRISMA 2020 statement (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) was conducted [25]. The review was registered in the Prospective International Registry for RH (PROSPERO) of the National Institute for Health Research (NIHR), with the registry code CRD42022332284 (https://www.crd.york.ac.uk/prospero).

The research question and search algorithm for the electronic databases were structured using the acronym PICO (patient, intervention, comparison, and outcomes): people with pain of musculoskeletal origin, treated with Träbert currents (also recognized as 2–5 current or Ultra-Reiz), compared with another physical therapy treatment or to a sham application, assessing pain reduction as the main outcome measure (evaluated with the visual analogue scale, numerical pain rating scale, algometry, and others) and changes in joint range as secondary outcomes (assessed with goniometry or an inclinometer) or disability assessed with functional questionnaires such as the Western Ontario and McMaster Universities Osteoarthritis (WOMAC) index, the knee injury and osteoarthritis scale (KOOS) or the Oswestry Disability Index (ODI).

Selection criteria

The following inclusion criteria were considered: (1) randomised clinical trials or controlled trials (RCT or CCT); (2) human studies; (3) participants older than 18 years; (4) articles in English or Spanish; (5) studies using TC alone or with another physical therapy intervention for the management of MSP; and (6) comparison with other physical therapy treatments with or without a sham application. On the other hand, the following exclusion criteria were considered: (i) CT treatments for other clinical conditions, (ii) pain associated with neurological disorders, and (iii) studies with missing/unavailable abstracts or texts.

Search strategy

Three independent researchers (EA-L, KD-G, and VJ-V) searched for clinical trials in six electronic databases with the last update on May 31, 2022: Medline (via PubMed), Scopus, Web of Science (WoS), CINAHL, Science Direct, and the PEDro database. The search algorithm was developed with keywords from the MeSH dictionary (Medical Subject Headings) (https://www.ncbi.nlm.nih.gov/mesh/). A meticulously curated set of keywords derived from the Medical Subject Headings (MeSH) dictionary was employed, including terms such as “Transcutaneous electric nerve stimulation”, “Electric stimulation therapy”, “Electric stimulation”, “Träbert current”, “Ultra-Reiz”, “Musculoskeletal pain”, “Musculoskeletal diseases”, “Myofascial pain syndromes”, “Arthralgia”, and “Tendinopathy”. The filters “clinical trials” and “randomized controlled trials” were used together with the Boolean terms “OR” and “AND” to elaborate the search algorithm: (“Transcutaneous Electric Nerve Stimulation” OR “Electric Stimulation Therapy” OR “Electric Stimulation” OR “Träbert current” OR “Ultra-reiz”) AND (“Musculoskeletal Pain” OR “Musculoskeletal Diseases” OR “Myofascial Pain Syndromes” OR “Arthralgia” OR “Tendinopathy”) Filters: Clinical Trial, Randomized Controlled Trial.

The researchers downloaded the search files for the databases (nbib, ris, or ciw format) to later upload them to the Rayyan platform (https://rayyan.qcri.org) [26]. The researchers first analysed the titles and abstracts of the articles according to the selection criteria, classifying them into three categories (‘included’, ‘maybe’, and ‘excluded’), to later download and review the full texts of the potentially eligible articles being evaluated. Discrepancies for the ‘maybe’ category were resolved through mediation and discussion with the principal investigator (HDB-O). The investigators independently analysed the following characteristics of the included clinical trials: participant demographics; screening sessions; assessments and instruments; follow-up period; TC treatment protocol; and outcome measures on variables of interest.

Quality and risk of bias of the articles

Three independent researchers (EA-L, KD-G, and VJ-V) reviewed the quality of clinical trials in the PEDro database. In the case of non-indexing, each one applied the scale to assess the quality of the studies, and any disagreement was resolved by the research team to establish consensus. RCT with scores greater than 5 were assessed as 'high quality' [27]. The risk of bias was assessed using the Cochrane Collaboration's RoB2 tool with the following criteria [28]: (1) randomisation process bias; (2) bias due to deviations from planned interventions; (3) missing outcome data bias; (4) outcome measurement bias; (5) reported outcome selection bias; and (6) general bias. Four investigators (EA-L, SC-M, KD-G, and VJ-V) extracted the data and independently rated each risk of bias criterion in one of the four categories of the RoB2 tool: high risk; low risk; some concerns, or unclear risk of bias [28]. A fifth evaluator (HDB-O) participated if there was a non-consensus for any of the criteria. Studies with two or more high risks of bias were judged to be of low quality. Subsequently, box plots and summary plots were constructed using the Robbins tool [29].

Evidence quality

The evidence quality for pain intensity and disability was evaluated using the Grading of Recommendation, Assessment, Development, and Evaluation (GRADE) rating tool, classifying the level of evidence into high, moderate, low, and very low-quality categories [30]. The researchers used the Guideline Development Tool (GDT) to create the results summary table (https://www.gradepro.org) [31].

Ethical approval

The conducted research is not related to either human or animal use.

Results

Search results

A total of 827 articles were obtained for the electronic databases reviewed via PubMed, *n* = 102; Scopus, *n* = 306; Web of Science, *n* = 26; CINAHL, *n* = 218; ScienceDirect, *n* = 172; and the PEDro databe, *n* = 0 (last update January 12, 2024). Duplicates were eliminated, resulting in a total of 735 for analysis. After reviewing the titles and abstracts, sixteen articles were obtained (maybe and included categories). The researchers adopted a consensus for these articles, discarding nine studies and including seven studies for the review. The exclusion reasons were due to treatment of musculoskeletal conditions with another electrical modality (TENS) (*n* = 7), case study report of TC (*n* = 1), and incomplete/unavailable article (*n* = 1). Figure 2 presents additional information and summarises the search strategy through the PRISMA flowchart [25]. The search strategy and its results can be reviewed in Appendix 1.

Assessment of the internal validity and risk of bias of the included studies

The internal validity of the articles was assessed using the Physiotherapy Evidence Database (PEDro) scale. First, the indexing search for the RCTs in this database was carried out but did not find a record of any of the studies included for this SR. Subsequently, three independent researchers (EA-L, KD-G, and VJ-V) evaluated the internal validity of the included studies using the PEDro scale (Table 1). 85.7% of the RCTs (*n* = 6) were assessed as high quality, with scores equal to or greater than five [27]. On the other hand, the report by Nurachma et al. [36] was the only one evaluated with low quality, obtaining four points according to PEDro. The best scores were observed for random assignment (crite-

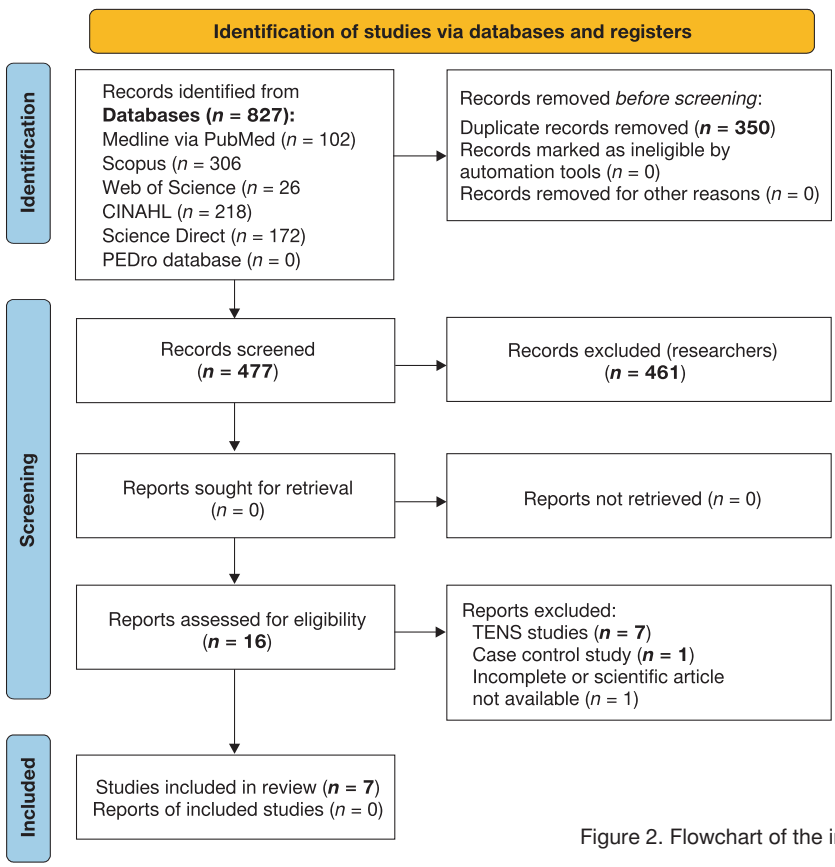

Figure 2. Flowchart of the included studies

Table 1. Characteristics of the items included

No.	Study	Author publication year country	Condition	PEDro SCORE	*n* males females Mean age ± *SD*	Study groups	Intervention	TC parameters	Sessions	Evaluations	Outcomes	Results
1	Effects of ultra Reiz current and tens on pain and functional ability in older patients with osteoarthritis knee	Sen et al. [32] (2013) India	Knee OA	6/10	*n* = 45 males = 11 females = 34 NS	EG: 15 (NS) CG 1: 15 (NS) CG 2: 15 (NS)	EG: TC + exercises (isometrics in OKC) CG 1: TENS + exercises (isometrics in OKC) CG 2: Exercises (isometrics in OKC)	I: tolerance level T: 30 min (treatment 1: 10 min; treatment 2: 20 min) CA: position EL IV (treatment 1) – cathode and anode in knee (treatment 2)	10 sessions (2 weeks)	T0: baseline (pretreatment) T1: week 1 T2: week 2 (post treatment)	– Pain intensity (WOMAC, section A) – Functional capacity (WOMAC, overall)	Pain intensity (WOMAC, section A): EG: T2* < T1* < T0 CG 1: T2* < T1* < T0 CG 2: T2* < T1* < T0 EG < CG 1 < CG 2 for T2* and T1 Functional capacity (WOMAC, overall): EG: T2* > T1* > T0 CG 1: T2* > T1* > T0 CG 2: T2* > T1* > T0 EG = CG 1 > CG 2 for T2* and T1
2	Effectiveness of the segmental treatment with Trabert current in patient with humeral epicondylitis	Pantoja et al. [33] (2015) Cuba	Lateral epicondylalgia	5/10	*n* = 60 males = 7 females = 53 35.5 ± NS	EG 1: 30 (28 females, 2 males) EG 2: 30 (25 females, 5 males)	EG 1: TC (segmental application) EG 2: TC (local application)	I: 60 to 80 mA T: 15 min CA: EL position I (EG 1) – local (elbow) (EG 2)	15 sessions (3 weeks)	T0: baseline (pretreatment) T1: week 1 T2: week 2 T3: week 3 (post treatment)	– Pain intensity (VAS) – Disability (BI-ADL) – Forearm ROM (observation)	Pain intensity (VAS): EG 1: T3 < T2 < T1 < T0 EG 2: T3 < T2 < T1 < T0 Disability (BI-ADL): EG 1: T3 > T2 > T1 > T0 EG 2: T3 > T2 > T1 > T0 Forearm ROM (observation): EG 1: T3 > T2 > T1 > T0 EG 2: T3 > T2 > T1 > T0 (subjective evaluation)
3	Effectiveness of the acupuncture treatment in patients with external humeral epicondylitis	Pantoja et al. [34] (2015) Cuba	Lateral epicondylalgia	5/10	*n* = 100 males =29 females = 71 44.5 ± NS	EG 1: 50 (33 females, 17 males) EG 2: 50 (38 females, 12 males)	EG 1: TC (segmental application) + acupuncture EG 2: TC (segmental application)	I: 60 to 80 mA T: 15 min CA: EL position I (EG 1) – local (elbow) (EG 2)	16 sessions (3 weeks)	T0: baseline (pretreatment) T1: week 1 T2: week 2 T3: week 3 (post treatment)	– Pain intensity (VAS) – Disability (BI-ADL) – Forearm ROM (observation)	Pain intensity (VAS): EG 1: T3 < T2 < T1 < T0 EG 2: T3 < T2 < T1 < T0 Disability (BI-ADL): EG 1: T3 > T2 > T1 > T0 EG 2: T3 > T2 > T1 > T0 Forearm ROM (observation): EG 1: T3 > T2 > T1 > T0 EG 2: T3 > T2 > T1 > T0 (subjective evaluation)
4	Efficiency of selected physiotherapeutic treatments for low back pain	Dakowicz et al. [35] (2016) Poland	LBP	5/10	*n* = 40 males = 9 females = 31 58 ± NS	EG: 15 (18 females, 2 males) CG: 15 (13 females, 7 males)	EG: TC CG: massage therapy	I: NS T: 15 min CA: local (low back)	10 sessions (2 weeks)	T0: baseline (pretreatment) T1: week 1 (post treatment)	– Pain intensity (VAS) – Disability (ODI) – Disability (RMQ) – Disability (Lattinen index) – Spine flexibility (Shober test)	Pain intensity (VAS): EG: T1 < T0 CG: T1 < T0 Disability (ODI): EG: T1* < T0 CG: T1* < T0 Disability (RMDQ): EG: T1* < T0 CG: T1* < T0 Disability (Lattinen index): EG: T1* < T0 CG: T1* < T0 Spine flexibility (Shober test): EG: T1* > T0 CG: T1* > T0

5	The effectiveness of short-term massage versus Träbert current therapy in patients with low back pain	Chwieśko-Minarowska et al. [19] (2019) Poland	LBP	6/10	*n* = 60 males = 15 females = 45 57 ± 11	EG: 30 (22 females, 8 males) CG: 30 (23 females, 7 males)	EG: CT CG: PTP (strengthening, flexibility and postural correction exercises)	I: 15 to 25 mA T: 15 min CA: position EL IV	11 sessions (2 weeks)	T0: baseline (pretreatment) T1: week 2 (posttreatment)	– Pain intensity (NPRS) – Disability (ODI) – Disability (RMQ) – Spine flexibility (Shober test)	Pain intensity (NPRS): EG: T1* < T0 CG: T1* < T0 Disability (ODI): EG: T1* < T0 CG: T1* < T0 Disability (RMQ): EG: T1* < T0 CG: T1* < T0 Spine flexibility (Shober test): EG: T1 > T0 CG: T1 > T0
6	Ultra-Reiz current appears to be more effective modality than interferential for people with knee osteoarthritis: a randomised block clinical trial	Ahangari et al. [18] (2020) Indonesia	Knee OA	6/10	*n* = 104 males = 37 females = 67 58 ± NS	EG: 52 (NS) CG: 52 (NS)	EG: CT + exercises (isometrics OKC – CKC) CG: IFC + exercises (isometrics OKC – CKC)	I: tolerance level T: 20 min CA: position EL IV	12 sessions (3 weeks)	T0: baseline (pretreatment) T1: week 3 (post treatment)	– Pain intensity (KOOS, p1-p9) – Symptoms (KOOS, s1-s5) – ADL (KOOS, a1-a17) – MRS (KOOS, sp1-sp5) – Quality of life (KOOS, q1-q4)	Pain intensity (KOOS, p1–p9): EG: T1* < T0 CG: T1 < T0 EG < CG for T1* Symptoms (KOOS, s1–s5): EG: T1 < T0 CG: T1* < T0 CG < SG for T1 ADL (KOOS, a1–a17): EG: T1 > T0 CG: T1* > T0 CG < SG for T1* Sports-recreational activities (KOOS, sp1–sp5): EG: T1* > T0 CG: T1 >T0 EG < CG for T1* Quality of life (KOOS, q1–q4): EG: T1* > T0 CG: T1 >T0 EG < CG for T1*
7	Efek electro therapy Trabert current and pulse burst knee osteo-arthritis pain grade II	Nurachma et al. [36] (2019) Indonesia	Knee OA	4/10	*n* = 4 males = NS females = NS 63 ± NS	EG: 2 (NS) CG: 2 (NS)	EG: TC CG: TENS-burst	I: NS T: NS CA: local (knee)	5 sessions (5 weeks)	T0: baseline (pretreatment) T1: week 1 T2: week 2 T3: week 3 T4: week 4 T5: week 5 (post treatment)	– Pain intensity (WOMAC, section A) – Functional capacity (WOMAC, overall)	Pain intensity (WOMAC, section A): EG: T5–1 < T0 CG: T5–T1 < T0 CG < SG for T5 Functional capacity (WOMAC, overall): EG: T5–1 < T0 CG: T5–T1 < T0 CG < EG for T5

a1–a17 – questions associated with activities of daily living (KOOS), ADL – activities of daily living (KOOS), BI-ADL – Barthel index for activities of daily living, CA – current application, CG – control group, CKC – closed kinematic chain, IFC – interferential current, EL – position of the electrodes in the column according to Träbert, I – current intensity, KOOS – Knee injury and Osteoarthritis Outcome Score, EG – experimental group, LBP – low back pain, NS – not specified, NPRS – numerical pain rating scale, OKC – open kinematic chain, OA – osteoarthritis, p1–p9 – questions associated with pain intensity (KOOS), PTP – physical therapy program, ODI – Oswestry Disability Index, RMDQ – Roland Morris Low Back Pain Questionnaire, ROM – range of motion, TC – Träbert current, TENS – transcutaneous electrical nerve stimulation, T – treatment time, T1,2…X – evaluations performed after the initial evaluation, s1–s5 – questions associated with symptoms (KOOS), sp1–sp5 – questions associated with sports/recreational activities (KOOS), SRA – sports or recreational activities (KOOS), VAS – visual analogue scale, WOMAC – Western Ontario and McMaster Universities Osteoarthritis index.

* *p*-value < 0.05

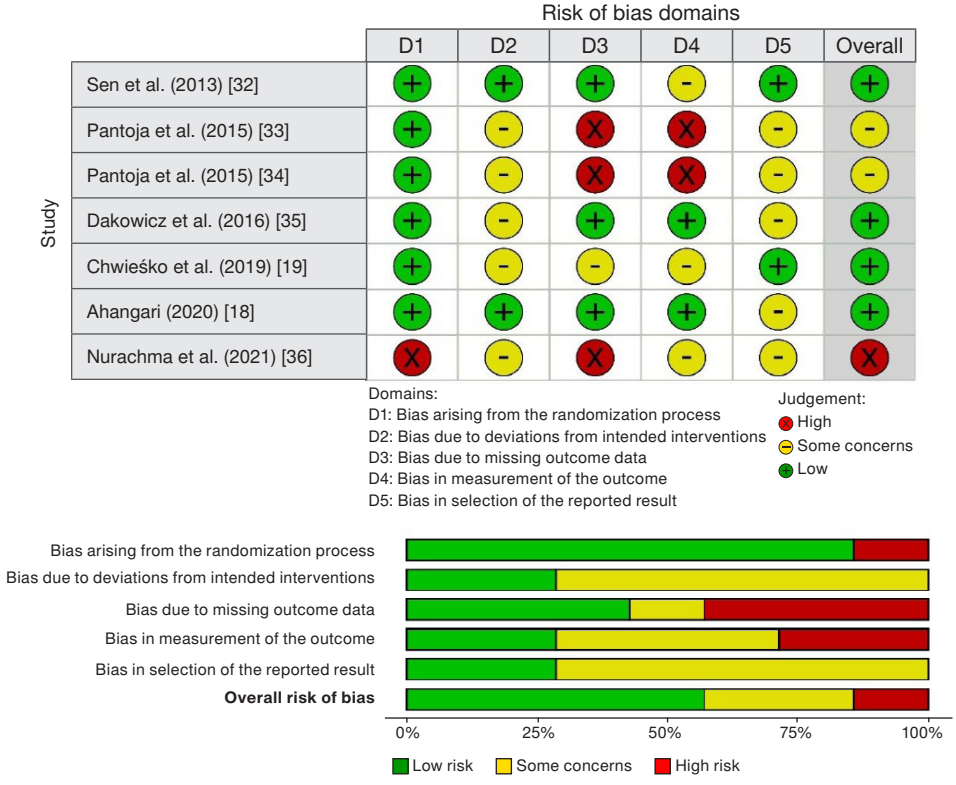

Figure 3. Risk of bias summary: reviewers' judgements of each risk of bias for each criterion as a percentage across all included studies

rion 2), baseline comparability (criterion 4), and outcome measurement follow-up (criterion 8). On the other hand, the articles show the greatest inconsistencies in the criteria for the blinding of participants, therapists, and evaluators (criterions 5 and 7).

Figure 3 shows the risk of bias for the RCTs: The randomisation process bias was rated as a low risk at 85.7% [18, 19, 32–35]; bias due to deviations from planned interventions was rated as some concern at 71.4% [19, 33–36]; bias due to missing outcome data was assessed as low [18, 32, 35] and high risk alike at 42.8% [33, 34, 36]; bias for outcome measurement was rated as some concern 42.8% [19, 32, 36]; bias associated with the selection of the reported outcome was rated as some concern at 71.4% [18, 33–36]; and the overall bias was rated as low-risk with 57.1% bias [18, 19, 32, 35].

Characteristics of included studies

Table 1 presents the characteristics of the included studies with their primary and secondary outcome measures. The articles were published between 2013 and 2021, with research conducted in Cuba, India, Indonesia, and Poland. The total population included 413 participants, with a mean age of 52.8, including 303 females and 110 males. It was observed that the main conditions treated included knee osteoarthritis (OA) pain [19, 32, 36], epicondylalgia [33, 34], and low back pain (LBP) [18, 35]. A total of 274 participants received TC alone [18, 33, 35, 36] or accompanied by interventions such as therapeutic exercises or acupuncture [19, 32, 34], while 139 participants were treated with other physical therapy interventions: electrotherapy (TENS or interferential currents) in patients with knee OA [19, 32, 36], massage therapy in patients with LBP [35], or therapeutic exercises in patients with knee OA [18, 19, 32].

TC treatments in patients with knee OA were carried out using longitudinal applications (EL IV) [19, 32, 36] and local applications in the knee [32, 36], as in patients with epicondylalgia, where longitudinal applications (EL IVandas elbow positions stands out [33, 34]. On the other hand, the study by Chwieśko-Minarowska et al. [19] reported the application of longitudinal TC (EL IV) in patients with LBP, while the study by Dakowicz et al. reported local applications in participants with the same clinical condition [35]. Two studies report the use of intensities at the tolerance level in patients with knee OA [19, 32], while in the studies by Pantoja et al. [33, 34], ranges of 60 to 80 mA were used in participants with epicondylalgia, although the stimulation threshold reached was not reported. On the other hand, Chwieśko-Minarowska et al. [19] reports applications between 15 and 25 mA without specifying the electrical sensation of the participants, while Dakowicz et al. [35] and Nurachma et al. [36] do not report the intensity used. The treatment times most commonly used were 15 minutes (4 studies) [18, 33–35], while Ahangari et al. [18] and Sen et al. [32] used 20 and 30 minutes of treatment, respectively, although in Sen's study the time was divided into 10 minutes of longitudinal application (EL IV) and 20 minutes of local application. Most of the clinical trials report several 10–15 treatment sessions carried out between two and three weeks [18, 19, 32–35], while only the study by Nurachma et al. [36] used five sessions once a week for five weeks of treatment.

Studies' primary and secondary outcome measures

All studies used instruments such as the visual analogue scale (VAS) [33–35], the numerical pain rating scale (NPRS) [19], the osteoarthritis index section A of WOMAC [32, 36], and the pain intensity section (questions 1 to 9) of KOOS [18] to assess the intensity of rest pain as the primary outcome measure. Furthermore, studies considered changes in disability before and after treatment using instruments such as the WOMAC index (participants with knee OA) [32, 36], the Barthel index (participants with lateral epicondylalgia) [33, 34],

and the Roland-Morris Questionnaire (RMQ) and ODI (participants with LBP) [19, 35]. All studies evaluated changes in outcome measures at two time points, before and after treatment, with a mean treatment time of 2 to 3 weeks [18, 19, 32, 33–35], whereas only one study evaluated changes in outcome measures at five points (one per week) for a treatment time of five weeks [36]. In addition, it is noted that none of the studies included in the review carried out follow-up evaluations once the treatment had finished.

Table 2 shows the results and statistical comparisons of the outcome measures in the experimental groups (EG) (within-group analysis). The studies report a statistically significant decrease in pain in all studies ($p < 0.05$) for the VAS [35], NPRS [19], WOMAC (section A) [32], and KOOS [18] instruments when comparing the baseline (before treatment) and at the end of CT treatment after an average treatment of 2 to 3 weeks. On the other hand, studies also report an overall decrease in disability that was statistically significant ($p < 0.05$) for the WOMAC index (overall) in participants with knee OA [32], for ODI in participants with LBP [19, 35], for the RMQ also for the same group of participants [19, 35], and the dimensions of activities of daily living (ADL), sports and recreational activities (SRA), and quality of life (QL) of the KOOS questionnaire in patients with OA knee [35]. Nurachma et al. was the only group to report no statistically significant changes in the WOMAC index, although there was a decrease in the score in participants with OA, reflecting a decrease in disability [36]. Despite the articles by Pantoja et al. [33, 34] documenting an improvement in pain intensity, disability, and ROM when using TC in lateral epicondylalgia, the quantitative information is not enough to show only the variations in descriptive statistics without inferential statistics.

Table 2. Results and statistical comparisons for the outcome measures in the TC groups between the included studies

Authors	Outcomes	Baseline (T0) mean ± *SD*	Evaluation at week 1 mean ± *SD*	Evaluation at week 2 mean ± *SD*	Evaluation at week 3 mean ± *SD*	Evaluation at week 4 or more mean ± *SD*	*p*-value
Sen et al. [32]	Pain intensity (points) (WOMAC, section A)	33.6 ± 5.42	/	8.7 ± 8.6	/		$p < 0.01$*
	Disability (points) (WOMAC, overall)	114.3 ± 19.87	76.9 ± 21.2	36.2 ± 27.7	/		
Pantoja et al. [33]	Pain intensity (cm) (VAS)	changes in outcome measures are reported, although without statistical analysis			/		not reported
	Disability (points) (BI-ADL)						
	ROM (grades) (Observation)						
Pantoja et al. [34]	Pain intensity (cm) (VAS)	changes in outcome measures are reported, although without statistical analysis			/		not reported
	Disability (points) (BI-ADL)						
	ROM (grades) (Observation)						
Dakowicz et al. [35]	Pain intensity (cm) (VAS)	6.0 ± 2.0	/	4 ± 2.5	/ $p < 0.01$* $p = 0.003$* $p < 0.05$*		$p < 0.05$*
	Disability (points) (ODI)	24.5 ± 4.5		10.5 ± 7.2			
	Disability (points) (RMQ)	16 ± 2.5		7 ± 4.0			
	Disability (points) (Lattinen index)	8 ± NE		3.6 ± NE			
	Spine flexibility (cm) (Shobber test)	4.5 ± NE		4.8 ± NE			
Chwieśko-Minarowska et al. [19]	Pain intensity (NPRS)	5 ± 3	/	4 ± 3.8	/ $p < 0.01$*		$p < 0.01$*
	Disability (points) (ODI)	32 ± 11		25 ± 13			
	Disability (points) (RMQ)	10 ± 1		7.5 ± 2	/ $p < 0.01$*		$p < 0.01$*
	Spine flexibility (cm) (Shobber test)	4.3 ± NE		7.5 ± NE			
Ahangari et al. [18]	Pain severity (points) (KOOS)	81.8 ± 9.4	/ 61.5 ± 18.0 56.6 ± 19.5 24.3 ± 23.7 22.8 ± 12.3		52.5 ± 19.5	/ $p = 0.403$* $p = 0.181$ $p = 0.074$* $p = 0.764$	$p = 0.045$*
	Symptoms (points) (KOOS)	86.2 ± 10.1					
	ADL (points) (KOOS)	86.3 ± 8.3					
	SRA activities (KOOS)	59.3 ± 15.5					
	Quality of life (KOOS)	51.4 ± 18.7					
Nurachma et al. [36]	Pain (WOMAC)	91.5 ± 20	/			61 ± 20	0.575
	Functional capacity (WOMAC)						

ADL – activities of daily living (KOOS), BI-ADL – Barthel index for activities of daily living, NPRS – numerical pain rating scale, KOOS – Knee injury and Osteoarthritis Outcome Score, ODI – Oswestry Disability Index, RMDQ – Roland Morris Low Back Pain Questionnaire, ROM – range of motion, VAS – visual analogue scale, WOMAC – Western Ontario and McMaster Universities Osteoarthritis index
* *p*-value < 0.05

Main result and meta-analysis

Data for the main outcome measures were analysed using the Cochrane Collaboration's Review Manager (RevMan) version 5.4 software. Figures 4 and 5 show the studies included in the meta-analysis for pain at rest and disability, respectively. Due to the diversity of the instruments used to quantify changes in pain and disability, standardised mean differences (SMD) were analysed to group the studies and make comparisons between them. Concerning pain intensity, the studies that had quantitative data were grouped into three comparisons: pain intensity at two weeks (Figure 4A), pain intensity at three weeks (Figure 4B), and pain intensity at the end of the study treatment (Figure 4C). The three comparisons of pain intensity show a pooled effect in favour of the control groups, although the confidence interval crosses or tops the line of no effect for all three figures. Although the CG seemed to exhibit a greater reduction in pain, the estimation of the standardised mean differences (SMD) did not show significant differences for the intensity of pain at rest between the groups at two weeks (SMD = 0.23, CI of 95% = –0.21, 0.47, *p*-value = 0.45), three weeks (SMD = 0.32, 95% CI = –0.06, 0.70, *p*-value = 0.10), and at the end of treatment (SMD = 0.25, 95% CI = –0.00, 0.50, *p*-value = 0.05) with small effect sizes in favour of the CG for the three instances of assessment. This MDS would not be relevant from a clinical point of view for CG, so it cannot be asserted that the comparison treatments (TENS, IFC, massage therapy, and exercises) are better than TC. On the other hand, the index of heterogeneity (I^2) was evaluated in the following categories [37]: homogeneity (0%), low (up to 25%), moderate (up to 50%), and high (75% or more). Figure 4 shows values of 79%, 0%, and 60% for pain intensity comparisons made at weeks two, three, and at the end of treatment, respectively, which is representative of the high variability between the studies for week two, low for week three, and moderate when all studies are considered at the end of treatment. This is an indicator for the comparison at the second week, and with less probability for the end of the treatment, that there is a greater probability that the differences in pain intensity are due more to the differences in the trials.

On the other hand, the quantitative analysis for disability was grouped into three comparisons: disability at two weeks (Figure 5A), disability at three weeks (Figure 5B), and disability at the end of treatment (Figure 5C). The forest plot considered the Chwieśko et al. [19] and Dakowicz et al. [35] studies twice as the disability results obtained for the ODI and RMQ instruments were included. Of the three comparisons of disability differences, a statistically significant pooled effect in favour of the CG is observed at two weeks (SMD = 0.55, 95% CI = -0.29, 0.82, *p*-value < 0.01) and at the end of treatment (SMD = 0.4, 95% CI = 0.17; 0.63, *p*-value < 0.01) with moderate effect sizes (*d* = 0.55) for week 2 and small (*d* = 0.29) for the end of treatment in favour of the CG. The MDS comparisons for week 2 and the end of treatment would support CG treatments such as (TENS, IFC, massage therapy, and exercises) more than CT in improving disability. On the other hand, the heterogeneity index (I^2) shows values of 72%, 0%, and 76% for the comparisons made at weeks 2, 3, and the end of treatment, respectively, which is representative of the high variability between the studies for weeks 2 and end of treatment and low by week 3, which may imply the probability that the differences in disability between the studies are due to chance rather than to real differences between them [37].

Publication bias

Figure 6 shows the funnel plots for the pain intensity (6A) and disability (6B) variables of the articles included. Both graphs show a greater distribution at the top of the funnels,

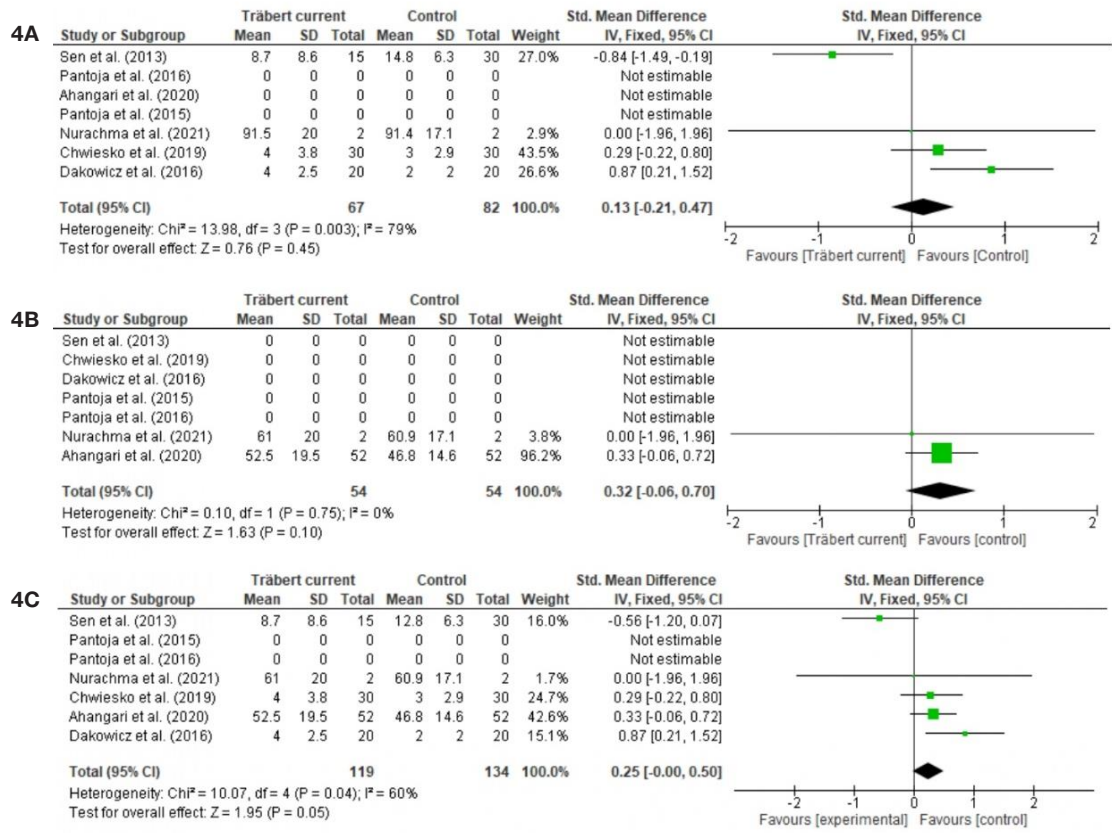

Figure 4. Forest plot for comparison of pain intensity at rest at 2 weeks (4A), 3 weeks (4B), and at the end of treatment, represented as a standardised mean difference (4C)

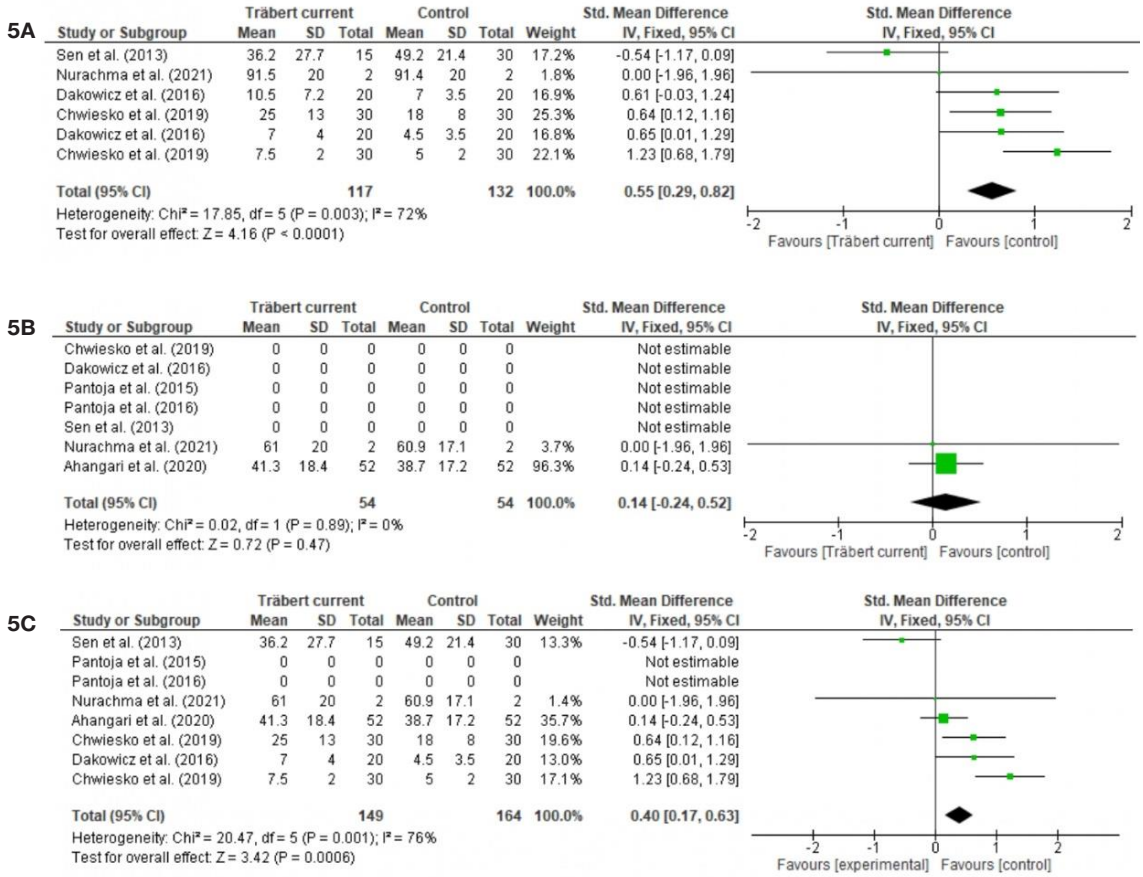

Figure 5. Forest plot for the comparison between groups of disability at 2 weeks (5A), 3 weeks (5B), and at the end of treatment, represented as a standardised mean difference (SMD) (5C)

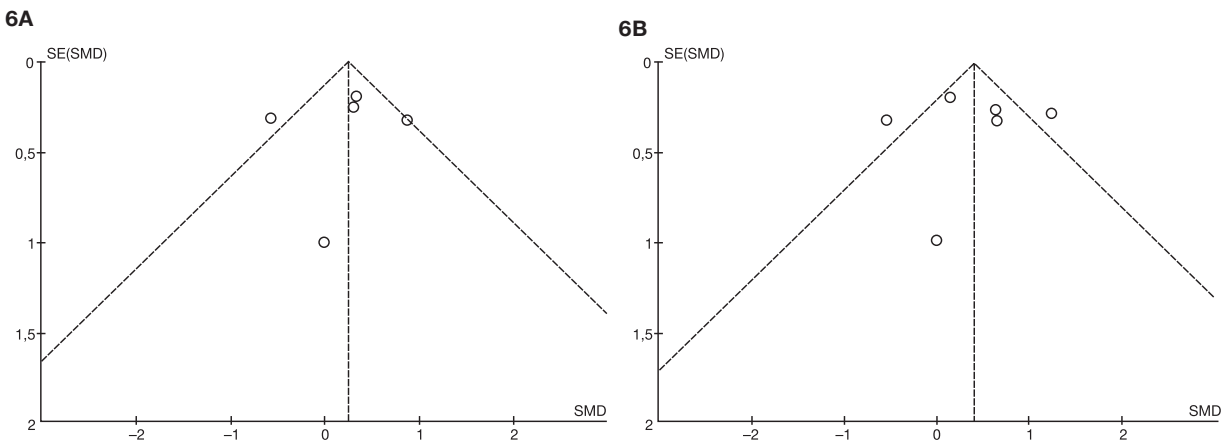

Figure 6. Funnel plot for included studies in relation to pain intensity (6A) and disability (6B) outcomes at the end of treatment

indicating good precision for the obtained outcome measures (SMD), which represents homogeneous sample sizes between the studies. On the other hand, a symmetrical distribution is observed for both graphs, which is an indicator of a lower publication bias. It should also be noted that the effect size (SMD) in some studies for both outcome measures appears outside the confidence interval (95%) or borders the line of no effect.

Table 3 shows the quality of the evidence according to the GRADE evaluation. The effectiveness of CT in reducing pain and disability at the end of treatment has been assessed as low due to the heterogeneity of the studies and the small effect sizes obtained. Although the studies report a decrease in pain and disability in both study groups (intragroup comparison), there are no statistically significant differences between them at the end of treatment, except for the disability outcome, where a small effect size (SMD = 0.4) was found, statistically significant in favour of the CG ($p < 0.01$), although with high heterogeneity.

Discussion

TC is a classic modality of electrotherapy described for analgesic purposes before the advent of TENS or IFC [17–19]. Its analgesic mechanisms are based on the combination of the electrochemical effects of galvanic current and the sensitive effects of TENS, added to a short pulse duration that allows it to reach high levels of stimulation while minimising

Table 3. Quality of the evidence by GRADE (grading of recommendation, evaluation, development, and evaluation) to use TC in a physiotherapy program for pain management and disability at the end of treatment (2 to 4 weeks)

Certainty assessment							No. of patients		Effect		Certainty	Importance
no. of studies	study design	risk of bias	inconsistency	indirectness	imprecision	other considerations	Träbert current be used in a physical therapy program	conventional physical therapy treatment	relative (95% CI)	absolute (95% CI)		
Pain intensity after treatment (range 2 weeks to 4 weeks)												
5[1,2,3,4,5]	randomised trials	serious[a]	serious[b]	not serious[c]	serious[d]	dose response gradient	119	134	–	SMD 0.25 SD fewer (0 to 0.5 fewer)	⊕⊕○○ Low	not important
Disability after treatment (range 2 weeks to 4 weeks)												
5[1,2,3,4,5]	randomised trials	serious[a]	serious[b]	not serious[c]	serious[d]	dose response gradient[e]	149	164	–	SMD 0.4 SD fewer (0.17 to 0.63 fewer)	⊕⊕○○ Low	not important

CI – confidence interval, SMD – standardised mean difference
[1] Ahangari et al. [18], [2] Chwieśko-Minarowska et al. [19], [3] Sen et al. [32], [4] Dakowicz et al. [35], [5] Nurachma et al. [36]
[a] Bias due to high outcome data for 42.8% of studies [33, 34, 36]; Outcome measurement bias was rated as some concern by 42.8% [19, 32, 36]; Bias due to selection of the reported outcome was rated as some concern at 71.4% [18,33–36].
[b] Heterogeneity was judged as very serious because the I^2 test showed moderate heterogeneity for all studies (60%).
[c] Indirect evidence was assessed as not serious because the studies directly compared the interventions and outcomes. All the studies included in the meta-analysis consider the population, intervention, comparison groups, and the report of the outcome.
[d] Range of the confidence interval was used as a criterion to assess the imprecision as well as the crossing of the line of no effect.
[e] A decrease in the intensity of pain and disability is observed in the studies when analysing the changes in the outcome measures for each group independently (intragroup), although the control group shows better results than the experimental group.

the risk of burning from other low-frequency currents [17]. This makes TC a versatile technique, allowing local (transregional) or longitudinal (Träbert positions in the spine) applications for pain management in different disorders.

This SR with MT-A aimed to determine the effectiveness of TC alone or as part of a treatment plan compared to other physical therapy interventions for musculoskeletal disorders. This was assessed by searching different electronic databases for clinical trials that used TC as an intervention in musculoskeletal disorders. Although the publication bias was low and the qualitative analysis showed analgesic benefits in favour of TC, the evidence was evaluated by the authors as low quality and unimportant due to the high heterogeneity of the studies and the small effect sizes obtained for outcomes of interest. Although the studies individually reported a quantitative and statistically significant pain and disability decrease for the EG, the MT-A did not appear to be conclusive in favour of TC or the conventional physical therapy program with TENS, IFC, massage therapy, or exercises in the treatment of conditions such as low back pain or knee OA [18, 19, 32, 35, 36]. The data show an apparent advantage in favour of the CG for relevant outcomes (especially disability), but without statistical significance or with significance but with high heterogeneity, which suggests that the proportion of variability in the outcomes of interest may be due to real differences in the trials, which makes it difficult to compare. However, it should be noted that the best results in favour of the CG appear particularly in those trials where the participants received therapeutic exercises in conjunction with another intervention (for example, TENS or IFC) as part of the program [19, 35, 36], so it is reasonable to assume that the analgesic effect or disability reduction achieved by the combination of interventions may be greater than one application of TC alone [33, 35, 36]. This is also evident when the trials that combined TC and therapeutic exercises in participants with knee OA were analysed, showing similar or lower means than the CG in the outcome measures at the end of treatment [19, 32]. The role of therapeutic exercise in reducing pain and disability for different MSP conditions (including knee OA and LBP) is known, so benefits are expected if it is incorporated into a treatment plan [38–40]. The foregoing makes it necessary to consider in new TC trials incorporating exercise in all the study groups with or without another additional treatment in the controls (ideally also supported by the evidence). This will not only make it possible to assess the effectiveness of adding TC to a physical therapy program, but will also ensure that the bioethical principle of beneficence is safeguarded by offering all study participants a treatment that will bring them benefit [41].

This SR included seven studies for qualitative analysis, but the MT-A could only be conducted with five trials due to the insufficient quantitative data and inferential analysis in the studies by Pantoja et al. [33, 34]. The author reported only descriptive information and subjective improvements in pain intensity (VAS), pronosupination ROM (observation), and disability (BI-ADL) in epicondylalgia patients without statistical analysis to support these changes. In addition, the same author compared two applications of TC (longitudinal and local application) without incorporating a control group, which would not be enough to support the evidence of TC despite the subjective improvements described. This reinforces the idea that the number of TC clinical trials appears to be limited.

The internal validity of the analysed trials seems generally acceptable (PEDro score equal to or greater than five for 85.7% of the studies), although there are cross-sectional methodological deficiencies associated with the absence or non-reporting of a concealed assignment, or blinding of the participants, evaluators, and/or therapists. As a result, the researchers evaluated some studies with a high or unclear risk of bias (D2, D3, and D5 of the Cochrane RoB2 tool), which could question

their methodology and results. This must be considered despite the favourable results on pain and disability reported by the authors, which are areas for improvement for new clinical trials. On the other hand, those studies that incorporated VAS, NPRS, WOMAC, and KOOS to evaluate the results of interest stand out because they are validated instruments used in clinical practice for evaluating pain and disability in conditions of LBP and knee OA: NPRS, ICC = 0.95; VAS: ICC = 0.97; correlation between NPRS and VAS, $r = 0.88–0.91$, $p < 0.01$; WOMAC-pain section, ICC = 0.86; WOMAC-section stiffness, ICC = 0.68; WOMAC-general, ICC = 0.89; KOOS, ICC > 0.70 [42–45].

This SR shows that the authors favoured both longitudinal (Electrode positions on the spine with Träbert) and local applications to treat the reported musculoskeletal conditions, mostly using the EL IV application for the management of LBP and knee OA [18, 19], except for one study that treated OA knee pain locally [36], and another that used the combination of the two applications in the same condition [32]. Similarly, Pantoja et al. compared longitudinal (EL I) and local application in participants with epicondylalgia. It is important to note that the main difference between both applications lies in the activation of different pain-modulating mechanisms. Local applications are based on the stimulation of large afferent fibres (A-beta fibres) and the activation of the pain gate theory together with the inhibitory effects of the galvanic current (fundamentally, the effects of the anode), which are close to 30% for TC [17, 46]. On the other hand, longitudinal applications have been associated with the activation of diffuse noxious inhibitory control (DNIC) centres, an endogenous modulation system with neurons in the brainstem that regulate nociceptive transmission from dorsal horn neurons in the spinal cord and which is activated by almost uncomfortable high-intensity thermal, mechanical, or electrical stimuli (which follows the principle 'one pain inhibits another pain') [23, 24, 47].

Likewise, it is known that the analgesia of electrotherapy is also mediated by the release of endogenous opioid peptides, so the participation of this mechanism could not be ruled out [21, 22, 48]. These substances not only promote analgesia but are involved in stress emotions and cognitive regulation of the pain response (neuromatrix theory of pain) [49]. The severity of the disorder and the presence or absence of central sensitisation (SC), a common condition in chronic musculoskeletal disorders characterised by an amplification of central nociceptive transmission and in which DNIC activity may be reduced, may influence the choice of one application over another [50, 51]. It should be noted that the presence of CS has been described in patients with chronic LBP and knee OA (same cases reported), so the most recommended applications for TC could be local over longitudinal ones [52, 53].

However, other variables come into play in the modulation of pain through electrotherapies, such as the intensity of the current (milliamps) and the treatment time [21, 22]. In line with the activation of the described analgesic mechanisms, longitudinal applications should reach the level of tolerance stimulation (high intensity, uncomfortable but not nociceptive), while local applications should induce sensory stimulation (current-induced paresthaesia sensation). Unfortunately, the studies do not make the stimulation level used clear in their procedures, except for the studies by Ahangari and Sen that report the use of intensities at the tolerance level, which is consistent with the longitudinal applications they used [18, 32]. On the contrary, it is observed that the reported treatment durations generally fall within the range of 10 to 15 minutes. However, there is a potential concern that this timeframe may not be adequate to elicit analgesic effects with TC. It is crucial to recognise that this aspect remains a point of contention in the field of electrotherapy, with applications described spanning from a few minutes to durations tailored to individual needs [53].

Finally, it is recommended for new clinical trials to maintain ten to fifteen sessions for 2 to 4 weeks of treatment, given the favourable results in pain and disability reduction described by each of the authors.

Limitations for this SR

This SR is the first to assess the analgesic effectiveness of TC in MSP disorders. The use of a transparent method to evaluate and report the evidence based on the PRISMA recommendations and the protocol registry (PROSPERO) is highlighted. The researchers recognise the following as the main limitations: (1) Despite the fact that six databases were searched for articles in English and Spanish, articles in other languages cannot be ruled out because the majority of the studies come from Indonesia, India, and Poland; (2) the authors acknowledge the existence of a TC study in patients with LBP but that could not be obtained; (3) the high heterogeneity of the articles does not allow the authors to present a conclusive analysis from the metadata, so the research question remains open; (4) some studies exhibit evident methodological limitations that have the potential to overestimate the effects of TC interventions or conventional physical therapy treatments.

Conclusion

TC is an electrotherapy modality that distinguishes itself from other currents by combining sensitive and galvanic effects, favouring high levels of stimulation, allowing clinicians to achieve various forms of analgesia. Despite being available on most electrotherapy equipment, it seems less known than other electrical resources such as TENS or FIC. This motivated researchers to develop the first SR associated with TC.

This review shows a pain and disability decrease for the groups treated with TC in conditions such as knee OA, LBP, and epicondylalgia. However, these improvements are not observable in the quantitative analysis when comparing the pooled studies due to the heterogeneity of the studies. The findings are insufficient to affirm whether TC is superior or inferior to traditional physical therapy treatments such as TENS, FIC, massage therapy, or therapeutic exercise.

The development of this review has highlighted the limited number of studies on TC and emphasised the necessity for new trials. While improvements have been made in certain methodological aspects, the doses and applications reported by the studies included in the review have been maintained. A suggestion for future clinical trials is to explore variations in longitudinal or local applications, incorporating therapeutic exercises into TC treatment. This approach considers the potential benefits of combining both interventions.

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Conflict of interests

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Appendix 1. Keywords and results by database (last updated January 12, 2024)

	KEYWORDS	PUBMED	SCOPUS	WOS	CINAHL	SCIENCE DIRECT	PEDro	TOTAL
S1	*"Transcutaneous Electric Nerve Stimulation"*	1.581	4.190	289	2.684	384		9128
S2	*"Electric Stimulation Therapy"*	3.125	14.873	261	16	123		18398
S3	*"Electric Stimulation"*	6.574	112.204	3.244	12.674	7.375		142071
S4	*"Träbert current"*	0	5	1	0	3		9
S5	*"Ultra-reiz"*	1	2	0	0	4		7
S6	S1 OR S2 OR S3 OR S4 OR S5	7.941	155.488	4.185	15.159	7.686		190459
S7	*"Musculoskeletal Pain"*	1.094	13.601	11.130	4.831	10.011		40667
S8	*"Musculoskeletal Diseases"*	665	33.230	2.347	12.176	5.172		53590
S9	*"Myofascial Pain Syndromes"*	457	2.173	237	1.728	1.047		5642
S10	*"Arthralgia"*	1.769	52.895	5.669	5.214	19.911		85458
S11	*"Tendinopathy"*	681	6.559	5.446	5.114	3.797		21597
S12	S7 OR S8 OR S9 OR S9 OR S10 OR S11	4.443	103.113	24.480	27.480	37.989		197505
S13	S6 AND S12	105	306	26	218	172	0	827